DESCRIPTION

CIRCUIT FOR DRIVING COLD CATHODE TUBES

Cross Reference to Related Applications

This application claims priority to United States Provisional Patent Application Serial No. 60/414,096, filed September 25, 2002. The disclosure of this application is hereby incorporated by reference in its entirety, including all figures, tables, and drawings.

Background of the Invention

[0001] The gaming industry is a billion dollar-a-year business. Profits are high, but overhead expenses, including the energy required to heat and cool a casino 24 hours a day, and the energy required to supply power to the gaming machines, can be staggering. With current energy supplies strained, and the cost of power is skyrocketing, gaming profits are being depleted. The displays of most gaming machines are back-lit by flourescent lamps. Flourescent lamps use a considerable amount of energy and produce a lot of heat. Further, when these lamps are provided with too much current, light output weakens and becomes irregular. Many circuits have been designed in an attempt to drive flourescent lamps and cold cathode flourescent lamps more efficiently (U.S. Patent No. 5,495,405, U.S. Patent No. 5,854,543, U.S. Patent No. 5,930,121, U.S. Patent No. 5,959,412, U.S. Patent No. 6,118,221). Replacing standard flourescent lamps used to back-light gambling machines with cold cathode tubes driven by an energy efficient, reliable circuit that produces little heat would prove to be a profitable savings for the gaming industry.

[0002] All patents, patent applications, provisional patent applications and publications referred to or cited herein, are incorporated by reference in their entirety to the extent they are not inconsistent with the explicit teachings of the specification.

Summary of the Invention

[0003] The invention involves a circuit for driving cold cathode tubes. An oscillator drives MOSFETs which are driven at a precise frequency. The MOSFETs drive resonant elements

including the cold cathode tube. The resonance circuit does not feedback to the oscillator therefore the circuit experiences no loading and can be placed up to about 18 feet from the cold cathode tube.

[0004] The circuit of the subject invention has an oscillator with a high side and low side MOSFET device. The oscillator drives high voltage MOSFETs which drive the resonance elements. The resonance elements include an inductive storage device, a resonance capacitor and the cold cathode tube. A start resonance and a run resonance are achieved and controlled by resistor/capacitor networks.

Brief Description of the Drawings

[0005] FIG. 1 is a schematic diagram showing a preferred embodiment of the circuit of the subject invention.

[0006] FIG. 2 is a circuit diagram of the preferred embodiment of the circuit shown in FIG. 1.

[0007] FIG. 3 is a circuit diagram of a plurality of the preferred embodiment of the circuit shown in FIG. 1 each driving a cold cathode tube while all are powered by a single input.

[0008] FIG. 4 is a schematic diagram of another preferred embodiment of the circuit of the subject invention.

[0009] FIG. 5 is a circuit diagram of the preferred embodiment of the circuit shown in FIG. 4.

[0010] FIG. 6 is a schematic diagram of the preferred embodiment of the circuit shown in FIG. 4 driving three cold cathode tubes.

[0011] FIG. 7 is a circuit diagram of the preferred embodiment of the circuit shown in FIG. 6.

[0012] FIG. 8 is a schematic diagram of another preferred embodiment of the circuit of the subject invention.

[0013] FIG. 9 is a schematic diagram of another preferred embodiment of the circuit of the subject invention.

Detailed Description of Invention

[0014] The invention involves a circuit to drive a cold cathode lamp. An oscillation circuit drives MOSFETs at a precise frequency to drive resonance elements including a single wound inductive storage device, a resonance capacitor and a cold cathode tube. Resonance frequency is controlled by resistor/capacitor networks that direct the oscillator to achieve a start-up frequency to cause the tube to conduct and the run frequency to illuminate the device. The circuit does not experience loading since the resonance elements do not feedback to the oscillator thus the intensity of the lamp does not vary. The subject circuit is extremely efficient using 80% of the input power to provide light and losing only 20% of the input power as heat. Further, the circuit, unlike conventional circuits used to power cold cathode lamps, can be placed a distance from the source allowing greater flexibility in its positioning and placement.

[0015] A particular advantage of the circuit of the subject invention is that it allows a cold cathode tube to be driven off-line by a conventional 120 volt (V) source. Therefore, the exemplified embodiments of the subject invention include direct current (DC) converter circuits. It is noted however that the subject circuit can be powered directly by a DC power source.

[0016] A schematic drawing of a preferred embodiment of the circuit of the subject invention is shown in FIG. 1. FIG. 2 provides a circuit diagram of that schematic drawing. In this embodiment, alternating current (AC) input **10** of from about 90 V to about 265 V and more particularly 120 V is directed to a DC converter circuit **12**. In this embodiment the DC converter circuit is a split voltage circuit that rectifies and filters the AC input to DC. Positive current is sent to a low DC voltage power source **14** which supplies power to the integrated circuit (IC)/ oscillator **16**. The oscillator **16** has a high side MOSFET driver and a low side MOSFET driver. The oscillator **16** drives high voltage MOSFETs **22**, **24** to drive the resonance elements which include a single wound inductive storage device **26**, a resonance capacitor **28** and a cold cathode tube **20**. A resistor/capacitor (R/C) network **18** ramps up the power to a resonance sufficient to cause the cold cathode lamp **20** to conduct. This first resonance, or start frequency, is for example, a resonance of 2500 V AC sufficient to charge a 4.2 mm X 18 inches cold cathode tube. A run program executed by another R/C network **30** brings the system to a second resonance, its run resonance, to maintain a constant, reliable source. For the 4.2 mm X 18 inches tube, the run resonance is about

800-850 V AC. The subject circuit is a sinusoidal inverter circuit that runs at a frequency of about 25 kilohertz (KHz) to about 100 KHz.

[0017] FIG. 3 is a circuit diagram of the preferred embodiment shown in FIG. 2 where a plurality of cold cathode lamps are powered by a single AC input. Each lamp is supported by the entire circuit shown in FIG. 2. Five lamps are being illuminated in FIG. 3, the efficiency of the circuit of the subject invention however allows any number of cold cathode lamps to be powered by a single AC input.

[0018] Another preferred embodiment of the circuit of the subject invention is shown in FIGs. 4 and 5. FIG. 5 provides the circuit diagram of the schematic shown in FIG. 4. In this embodiment, AC input **10** enters a DC converter circuit **13** that is a full wave circuit. A DC blocking capacitor **32** is therefore included in the subject embodiment. The circuit comprises a single R/C network **31** to control resonance frequency. In this embodiment, a filter capacitor **34** has been added to the resonance elements. A current sensor **36** detects a lamp outage and will shut down the oscillator **16**. This preferred embodiment is particularly advantageous when used to illuminated more than one cold cathode tube. FIGs. 6 and 7 show that only the resonance elements and current sensor need to be repeated when adding further tubes to the circuit. The multiple lamp system is controlled by a single RC network **31** and is driven by a single oscillator **16** which decreases the cost of the circuit. If the current sensor **36** detects a lamp outage in the multiple lamp system, the resonance elements supplying that lamp are disconnected from the circuit.

[0019] FIGs. 8 and 9 is a schematic drawing of another preferred embodiment of the circuit of the subject invention. In this embodiment, the current supplied to the lamp is controlled by regulating the supply voltage. A constant current feedback circuit **38** monitors voltage and controls the current supplied to the cold cathode tube.

[0020] It is understood that the foregoing examples are merely illustrative of the present invention. Certain modifications of the articles and/or methods employed may be made and still achieve the objectives of the inventions. Such modifications are contemplated as within the scope of the claimed invention.